(12)   EUROPEAN PATENT APPLICATION

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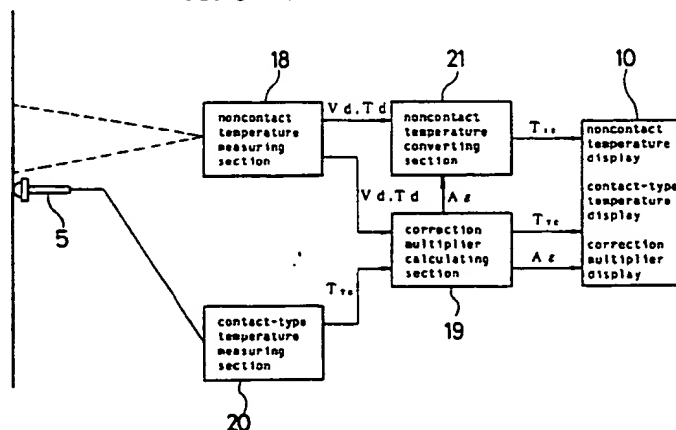   Meguro-ku, Tokyo (JP)

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(54)   Temperature measuring apparatus

(57)   To provide a temperature measuring apparatus making it possible to automatically calculate a correction multiplier by assuming the data measured by a contact-type thermometer as a true value and always accurately measure temperature by the noncontact method in accordance with the correction multiplier. The temperature measuring apparatus comprises noncontact- and contact-type thermometers for measuring the temperature of a temperature measurement object, arithmetic means for calculating a correction multiplier for correcting an error of data measured by the noncontact-type thermometer in accordance with the data measured by the noncontact-type thermometer and a value measured by the contact-type thermometer and moreover calculating a correction value by correcting the data measured by the noncontact-type thermometer in accordance with the correction multiplier, and display means for displaying the measured value and the correction value.

FIG. 5

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Description

Background of the Invention

The present invention relates to an improved temperature measuring apparatus using a noncontact-type thermometer, particularly to a temperature measuring apparatus capable of automatically correcting an error of a measured value due to a difference of the emissivity, reflectivity, or transmittance of a temperature measurement object.

A thermometer for measuring the surface temperature of an object is roughly divided into the following two types. One is a contact-type thermometer which measures the temperature of an object by bringing the temperature sensing section of the thermometer into contact with the surface of the object and the other is a noncontact-type thermometer which measures the temperature of an object by detecting infrared energy emitted from the surface of the object.

Because the noncontact-type thermometer has more advantages than the contact-type thermometer, it is recently used at various places. The above advantages include that heat is only slightly transferred to and from the surface of a temperature measurement object, the surface of the temperature measurement object is not damaged, and the response speed is high.

However, the noncontact-type thermometer has the following problems in view of its measuring theory. That is, (1) for a value measured by the noncontacttype thermometer, the quantity of infrared energy emitted from the surface of a temperature measurement object must be corrected depending on the material or the surface state of the object because the quantity of infrared energy depends oil the material or the surface state of the object.

Moreover, 2) a measured value includes an error because infrared energy coming from places other than the surface of the temperature measurement object in addition to the infrared energy emitted from the surface of the object reflects on the surface of the object and it is detected.

As for the above problem (1) correction values (emissivities) classified in accordance with the material or the surface state of the object are selected out of a list in a document, set to the noncontact-type thermometer correction device as parameters, and measured. However, the correction values in the document are experimentally obtained. Thereafter, it is uncertain whether the values are suitable for the material or the surface state of an actual temperature measurement object and thus, a measured value easily includes an error depending on a selected parameter. As for the problem 2) it is believed in many cases that a value displayed by the noncontact-type thermometer including an error is a true value.

Therefore, to solve the above problems, it is hitherto believed that temperature can also accurately be measured by the noncontact-type thermometer by simultaneously using the contact-type thermometer and thereby, manually correcting an error in accordance with the temperature of a temperature measurement object measured by the contact-type thermometer.

However, the above manual error correction causes artificial errors and moreover, a value measured by the contact-type thermometer cannot instantaneously be used for error correction of the noncontact-type thermometer. Therefore, problems occurs that the value measured by the contact-type thermometer already changes at the time of correction and resultingly, no accurate correction value can be obtained.

Summary of the Invention

The present invention is made to solve the above problems and its object is to provide a temperature measuring apparatus for automatically calculating a correction multiplier for correcting data measured by a noncontact-type thermometer to a true value by using data measured by a contact-type thermometer as a true value in accordance with the data measured by the contact- and noncontact-type thermometers, correcting the data measured by the noncontact-type thermometer in accordance with the correction multiplier, and always accurately measuring temperature by the noncontact method. It is another object of the present invention to provide a temperature measuring apparatus having a function for verifying whether the measurement environment is proper or not in accordance with a correction multiplier.

The temperature measuring apparatus of the present invention for achieving the above objects comprises a noncontact-type thermometer for measuring the temperature of a temperature measurement object in accordance with transfer of heat radiation to and from the temperature measurement object, a contact-type thermometer for measuring the temperature of the temperature measurement object by bringing a sensor section into contact with the surface of the temperature measurement object, arithmetic means for calculating a correction multiplier for correcting an error of data measured by the noncontact-type thermometer in accordance with data measured by the noncontact type thermometer and a value measured by the contact-type thermometer and moreover calculating a correction value by correcting the data measured by the noncontact-type thermometer in accordance with the correction multiplier, and display means for displaying the measured value and the correction value.

It is possible to properly select a sensor out of various sensors including a thermocouple and a thermistor as the contact-type thermometer in accordance with a purpose. As for the noncontact-type thermometer, it is preferable to use a thermopile or a thermistor bolometer as its infrared detector. Moreover, the display means can use aurally recognizing means in addition to visually recognizing means.

According to the temperature measuring apparatus

of the present invention, a measurer can correct an error of data measured by a noncontact-type thermometer set separately from a temperature measurement object in accordance with a temperature measured by bringing the sensor section of a contact-type thermometer into contact with the surface of the temperature measurement object and recognize an error correction data, that is, a correction multiplier through a display unit.

Brief Description of the Drawings

Fig. 1 is a side view of the temperature measuring apparatus of an embodiment of the present invention;
Fig. 2 is a top view of the temperature measuring apparatus shown in Fig. 1;
Fig. 3 is a front view of the temperature measuring apparatus shown in Fig. 1;
Fig. 4 is an enlarged view of the switch panel of the temperature measuring apparatus shown in Fig. 1;
Fig. 5 is a block diagram of the internal circuit of the temperature measuring apparatus shown in Fig. 1;
Fig. 6 is a schematic view showing a procedure for measuring temperature by using the temperature measuring apparatus shown in Fig. 1; and
Fig. 7 is a schematic view showing displayed details by a liquid crystal display section when measuring temperature by using the temperature measuring apparatus shown in Fig. 1.

Detailed Description of the Preferred Embodiment

An embodiment of the present invention is described below by referring to the accompanying drawings.
As shown in Figs. 1 to 4, the temperature measuring apparatus 1 of this embodiment is provided with a noncontact-type thermometer 3 set in a body case 2, a sensor section 5 supported by a holder 4 laterally protruded from the body case 2, and a contact-type temperature measuring section set in the body case 2 the same as the noncontact-type thermometer 3 is. The sensor section 5 is connected via a cable 6 to a circuit of the contact-type temperature measuring section in the body case 2.
Part of the body case 2 serves as a grip 7 on which a laser switch 8 for emitting a pointing laser beam and a hold switch 9 for temporarily stopping display and determining correction data are set, as shown in Fig. 3.
Moreover, a switch panel 11 shown in Fig. 4 is set below a liquid crystal display section 10. The switch panel 11 is provided with an ON switch 12 for turning on a power supply, an OFF switch 13 for turning off the power supply, a CAL switch 14 for setting a correction measurement mode or returning the mode to the current state, a MODE switch 15 for switching between contact-and noncontact-type measurement modes, and a correction multiplier setting switches 16 and 17 for set-

ting the value of correction multiplier A_ε.

A schematic view of the circuit configuration set in the body case 2 is shown in Fig. 5 in the form of a block diagram. Measured data for the output Vd of a detector (e.g. thermopile) for detecting the infrared energy emitted from a temperature measurement object, measured by a noncontact temperature measuring section 18 (an optical section for detecting infrared radiation) and the temperature Td of the detector are sent to a correction multiplier calculating section 19. Measured data inputted to a contact-type temperature measuring section 20 from the sensor section 5 is converted to a temperature value T_{TC} and sent to the correction multiplier calculating section 19. In the correction multiplier calculating section 19, the correction multiplier A_ε is calculated through the following steps in accordance with the received data.

First, the temperature Td of the detector sent from the noncontact temperature measuring section 18 and the temperature value (temperature of the temperature measurement object) T_{TC} sent from the contact-type temperature measuring section 20 are converted to an infrared energy quantity corresponding to each temperature value.

Temperature of detector: Td → Infrared energy quantity: Ld

Temperature of temperature measurement object: T_{TC} → Infrared energy quantity: L_{TC}

The correction multiplier A_ε is obtained from the following expression in accordance with the converted energy quantities.

$$A_\varepsilon = Vd/(L_{TC} \cdot Ld)$$

The result of calculating the above expression represents that the temperature measurement object fully reflects disturbances and only the influence of disturbances is measured for $A_\varepsilon = 0$. For $A_\varepsilon = 1$, however, the result represents that the temperature measurement object fully absorbs disturbances and measurement is performed under the condition in which the influence of disturbances is not included.

Moreover, for $A_\varepsilon > 1$, it is considered that the following influence of disturbances occurs due to the relation between the temperatures of the temperature measurement object and the detector.

That is, when the temperature of the temperature measurement object is higher than that of the detector, a disturbance producing source with a temperature higher than that of the temperature measurement object is present. When the temperature of the temperature measurement object is lower than that of the detector, a disturbance producing source with a temperature lower than that of the temperature measurement object is present. Therefore, by using a correction multiplier (range of A > 1) including disturbances, it is possible to identify the influence of the disturbance producing source on the correction multiplier A_ε. The correction multiplier A_ε described above is sent to a noncontact

temperature converting section 21 and the above Vd and Td are sent to the noncontact temperature converting section 21 from the noncontact temperature measuring section 18. Then, a correction value T_{IR} of the noncontact-type thermometer 3 is converted by the noncontact temperature converting section 21 through the following steps.

First, to obtain the infrared energy quantity (L_{IR}) corresponding to the correction value T_{IR}, the temperature Td of the detector is converted to an infrared energy quantity.

Temperature of detector: Td → Infrared energy quantity: Ld

The infrared energy quantity L_{IR} is obtained from the following expression in accordance with the converted infrared energy quantity.

$$L_{IR} = Vd/A_\varepsilon + Ld$$

The infrared energy quantity L_{IR} obtained from the above expression is converted to a temperature to obtain the correction value T_{IR} of the noncontact-type thermometer 3.

Infrared energy quantity: Ld → Correction value of noncontact-type thermometer 3: T_{IR}

The correction value T_{IR} thus obtained is displayed on the liquid crystal display section 10 together with the value measured by the contact-type thermometer used to calculate A_ε and the correction multiplier A_ε.

Moreover, when noticing the expression for obtaining L_{IR}, the infrared energy quantity L_{IR} is not changed by any value of A_ε when the value Vd is 0 (that is, when heat radiation is not transferred to and from a temperature measurement object). Therefore, when considering this case, it is necessary to make it impossible to calculate the correction multiplier A_ε except the case in which transfer of heat radiation to and from the temperature measurement object is kept at a certain level or higher.

Moreover, it is preferable to add a correction formula for correcting a temperature drift according to a detector or an optical characteristic to the detector output Vd.

It is necessary to perform actual measurement in accordance with the procedure shown in Fig. 6. First, the mode is changed to the calibration mode under the state shown in Fig 6(a) and the surface temperature of a temperature measurement object 22 with which the sensor section 5 contacts under the state shown in Fig. 6(b). Then, temperature is measured by the noncontact-type thermometer 3 under the state shown in Fig. 6(c) to determine the infrared energy quantity emitted from the surface of the temperature measurement object 22, the correction multiplier A_ε is calculated under the state shown in Fig. 6(d), and temperature after converted by the correction multiplier A_ε is displayed.

To measure temperature in the automatic error correction mode, operations are performed in accordance with the procedure shown in Fig. 7. That is, when the ON switch 12 of the switch panel 11 is pressed, all segments of the liquid crystal display section 10 are turned on to show that the temperature measuring apparatus 1 starts as shown by S_1 in Fig. 7. Immediately after that, the state is set in which measurement can be performed in the measuring mode used before the power supply is stopped last time as shown by S_2 or S_3 in Fig. 7.

S_2 shows the display of the mode for performing measurements by using the noncontact-type thermometer 3 and S_3 shows the display of the mode for performing measurement by using a contact-type thermometer. To change the measurement mode from S_2 to S_3 or S_3 to S_2, it is necessary to press the MODE switch 15 on the switch panel 11.

Then, to shift to the correction multiplier measuring mode shown by S_4 in Fig. 7, a temperature value measured by a contact-type thermometer under the condition for deciding the correction multiplier A_ε is determined by pressing the CAL switch 14. Then, segments of CAL showing the correction multiplier measuring mode and a temperature value indicated by the contact-type thermometer are displayed on the liquid crystal display section 10.

Then, by pressing the hold switch 9, a temperature value measured by the noncontact-type thermometer 3 under the condition for deciding the correction multiplier A_ε is determined as shown by S_5 in Fig. 7. In this case, segments of CAL showing the correction multiplier measuring mode and the temperature value indicated by the contact-type thermometer determined in the above stage are displayed and also, a temperature value (for $A_\varepsilon = 1$) measured by the noncontact-type thermometer 3 is displayed.

Moreover, when the decided correction multiplier A_ε is larger than 1 while the hold switch 9 is pressed again, the screen shown by S_6 in Fig. 7 appears which shows that an error due to external heat radiation occurs in a measured value by flickering a multiplier symbol because the correction multiplier A_ε is larger than 1.

However, when the decided correction multiplier A_ε ranges between 0 and 1 (both excluded), the screen shown by S_7 in Fig. 7 appears in which the correction multiplier A_ε is kept in the normal range and each segment does not flicker because the temperature measuring apparatus 1 normally operates.

When the correction multiplier A_ε is not decided because conditions necessary for deciding the correction multiplier A_ε are not satisfied, the screen shown by S_8 in Fig. 7 appears in which a temperature value indicated by the contact-type thermometer and a temperature value indicated by the noncontact-type thermometer 3 are shown by the symbol "-----" representing that the values are indeterminate and the value of A_ε is displayed as "or (OVER)".

By pressing the CAL switch 14, the state shown by S_6 or S_7 in Fig. 7 is returned to the state shown by S_2 in Fig. 7. However, when the state shown by S_8 in Fig. 7 appears, the state is displayed for several seconds and then automatically returned to the screen shown by S_4 in Fig. 7.

The temperature measuring apparatus of the present invention makes it possible to correct an error of a value measured by a noncontact-type thermometer set separately from a temperature measurement object in accordance with the temperature measured by bringing the sensor section of a contact-type thermometer into contact with the surface of the temperature measurement object and moreover, the temperature measuring apparatus allows a measurer to recognize the error correction data, that is, a correction multiplier by a display unit.

Moreover, when external heat radiation influences the heat, radiation between the temperature measurement object and the temperature measuring apparatus, the temperature measuring apparatus makes it possible to set a correction multiplier including the external heat radiation.

Furthermore, when an accurate correction value cannot be obtained because the heat radiation between the temperature measurement object and the temperature measuring apparatus is low, the temperature measuring apparatus displays for recognition by the measurer that correction has not been made.

Furthermore, even when an error is included in a measured temperature value of the temperature measurement object because external heat radiation influences the heat radiation between the temperature measurement object and the temperature measuring apparatus, it is possible to recognize the error.

Furthermore, it is possible to display a correction multiplier of a noncontact-type thermometer and the data (e.g. value indicated by a contact-type thermometer) obtained when the correction multiplier is decided as well as a value indicated by the noncontact-type thermometer during measurement on the same screen, thereby enabling the measurer to understand the corrected condition.

Therefore, it is possible to provide a temperature measuring apparatus realizing highly accurate noncontact-type temperature measurement by combining advantages of a noncontact-type thermometer with those of a contact-type thermometer.

Claims

1. A temperature measuring apparatus comprising a noncontact-type thermometer for measuring the temperature of a temperature measurement object in accordance with transfer of heat radiation to and from the temperature measurement object, a contact-type thermometer for measuring the temperature of the temperature measurement object by bringing a sensor section into contact with the surface of the temperature measurement object, arithmetic means for calculating a correction multiplier for correcting an error of data measured by the noncontact-type thermometer in accordance with data measured by the noncontact-type thermometer and a value measured by the contact-type thermometer and moreover calculating a correction value by correcting the data measured by the noncontact-type thermometer in accordance with the correction multiplier, and display means for displaying the measured value and the correction value.

2. The temperature measuring apparatus according to claim 1, wherein the sensor section of the contact-type thermometer is removably held by a holder set to the body case of the temperature measuring apparatus and the contact-type thermometer and the noncontact-type thermometer are integrally built in the body case.

3. The temperature measuring apparatus according to claim 1, wherein a correction multiplier is set which includes external heat radiation serving as a disturbance factor in addition to the heat radiation between the temperature measurement object and the noncontact-type thermometer.

4. The temperature measuring apparatus according to claim 1, wherein the display means displays that an accurate correction value has not been determined when the heat radiation between the temperature measurement object and the noncontact-type thermometer is smaller than a predetermined value.

5. The temperature measuring apparatus according to claim 1, wherein it is possible to confirm that an error is included in measured temperature data of the temperature measurement object when external heat radiation influences the heat radiation between the temperature measurement object and the noncontact-type thermometer.

6. The temperature measuring apparatus according to claim 1, wherein a correction multiplier of the noncontact-type thermometer, data when the correction multiplier is decided, and a value indicated by the noncontact-type thermometer during measurement are displayed on the same screen.

7. The temperature measuring apparatus according to claim 1, wherein the contact-type thermometer uses a thermocouple surface-temperature sensor and the noncontact-type thermometer uses a thermal detector.

8. The temperature measuring apparatus according to claim 1, wherein the display means displays which of a contact-type thermometer and a noncontact-type thermometer is more suitable for measurement in accordance with the measurement condition.
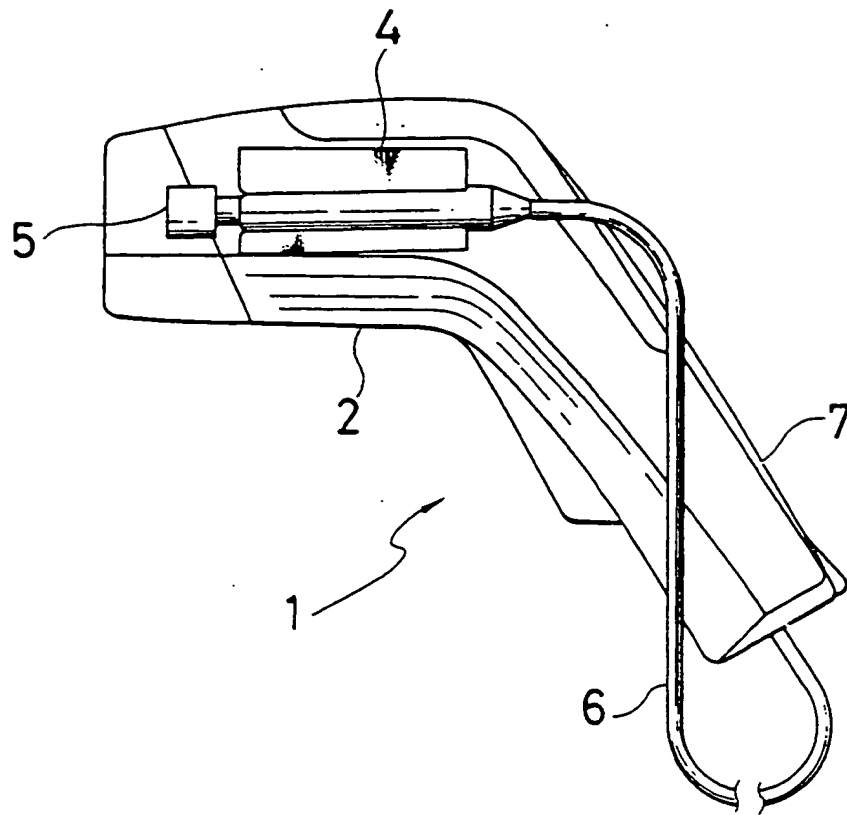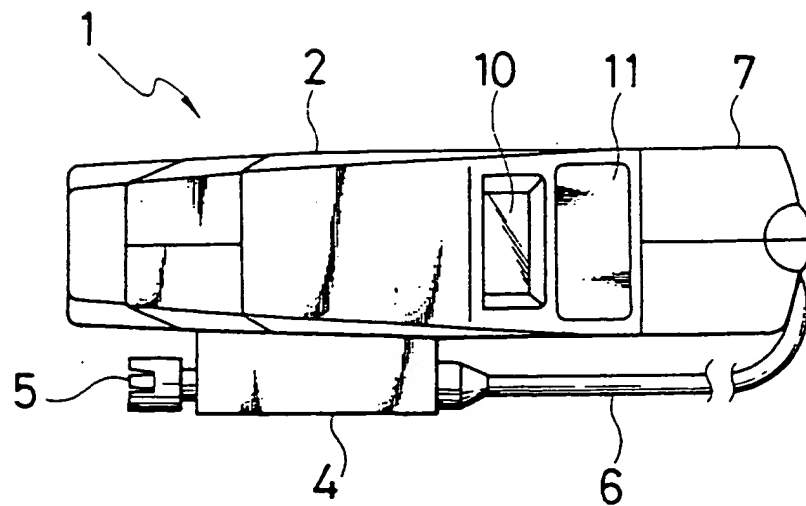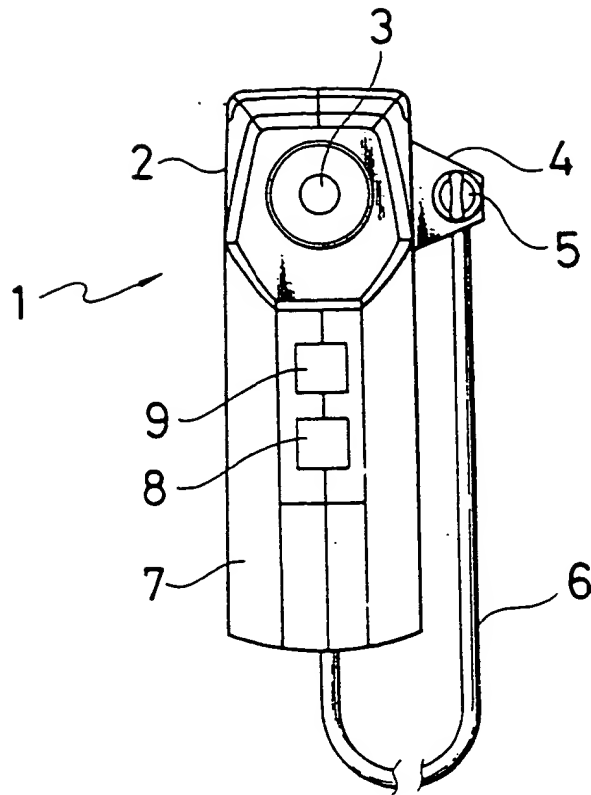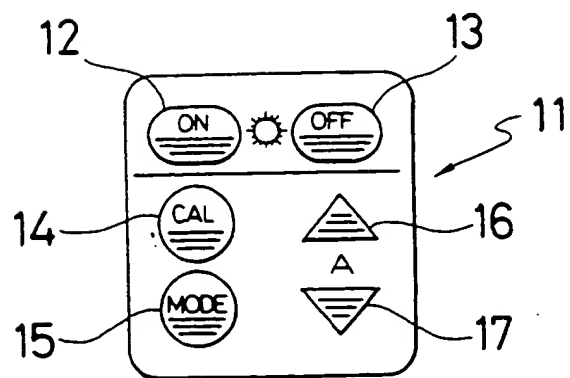
FIG . 1

FIG . 2

FIG. 3

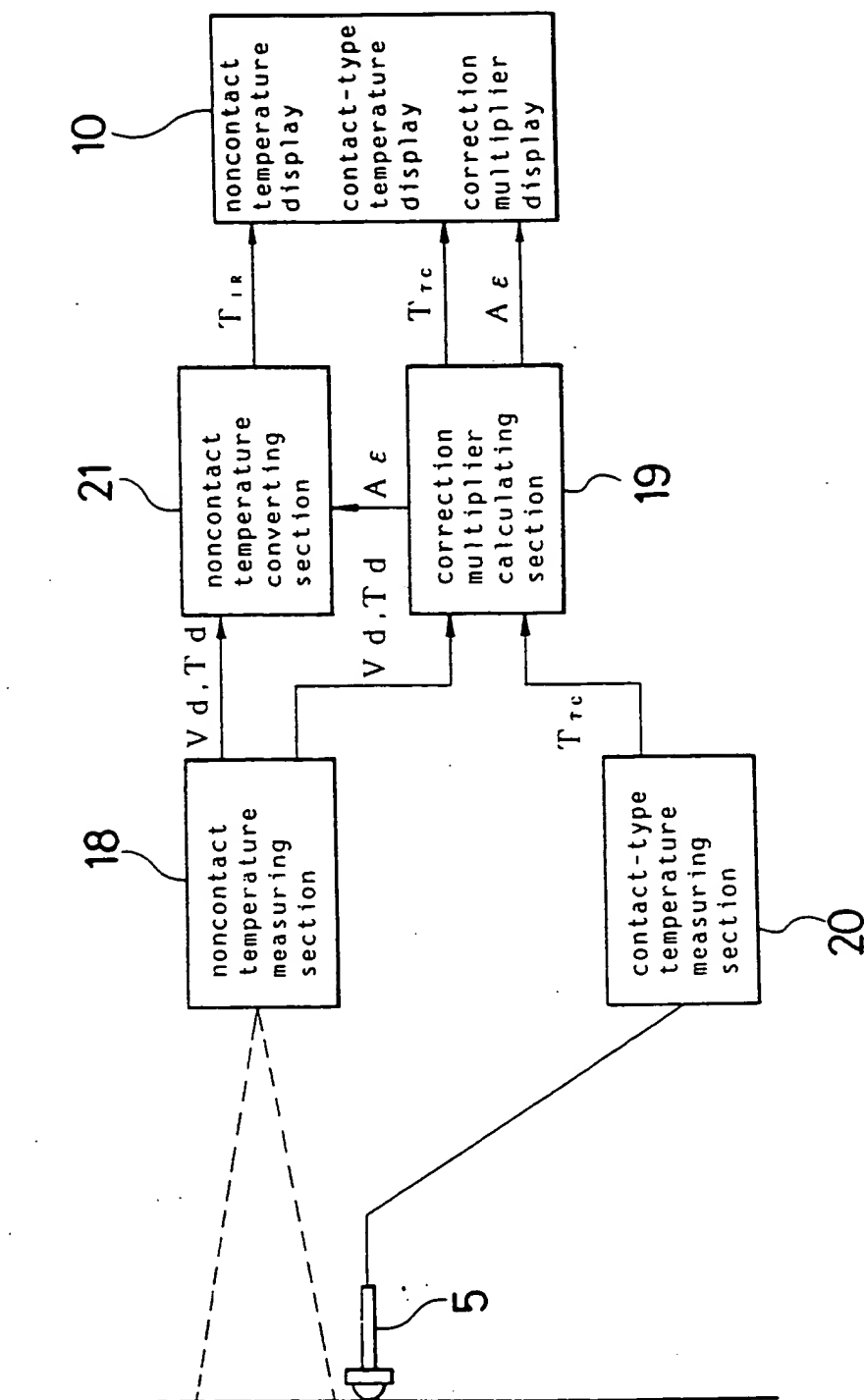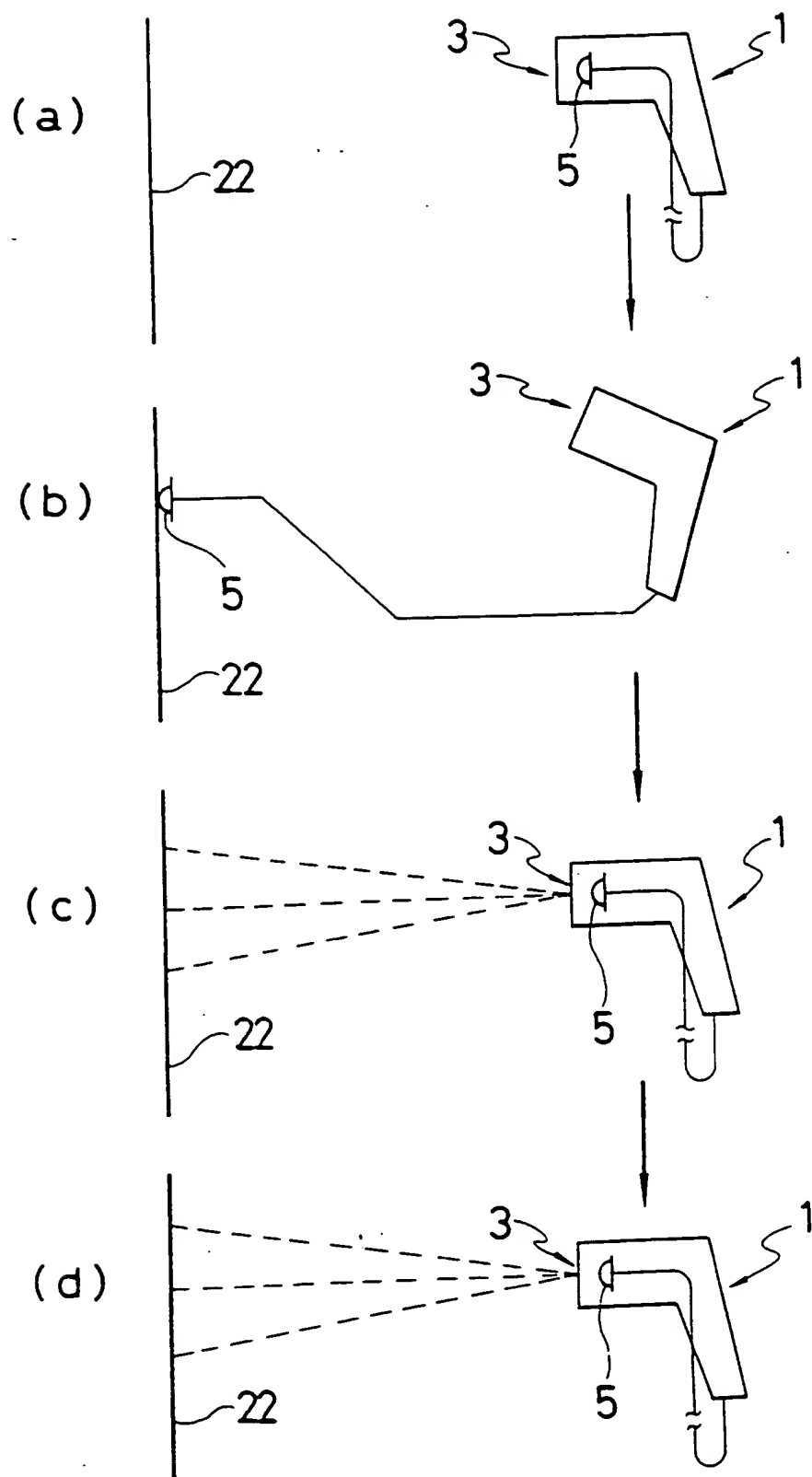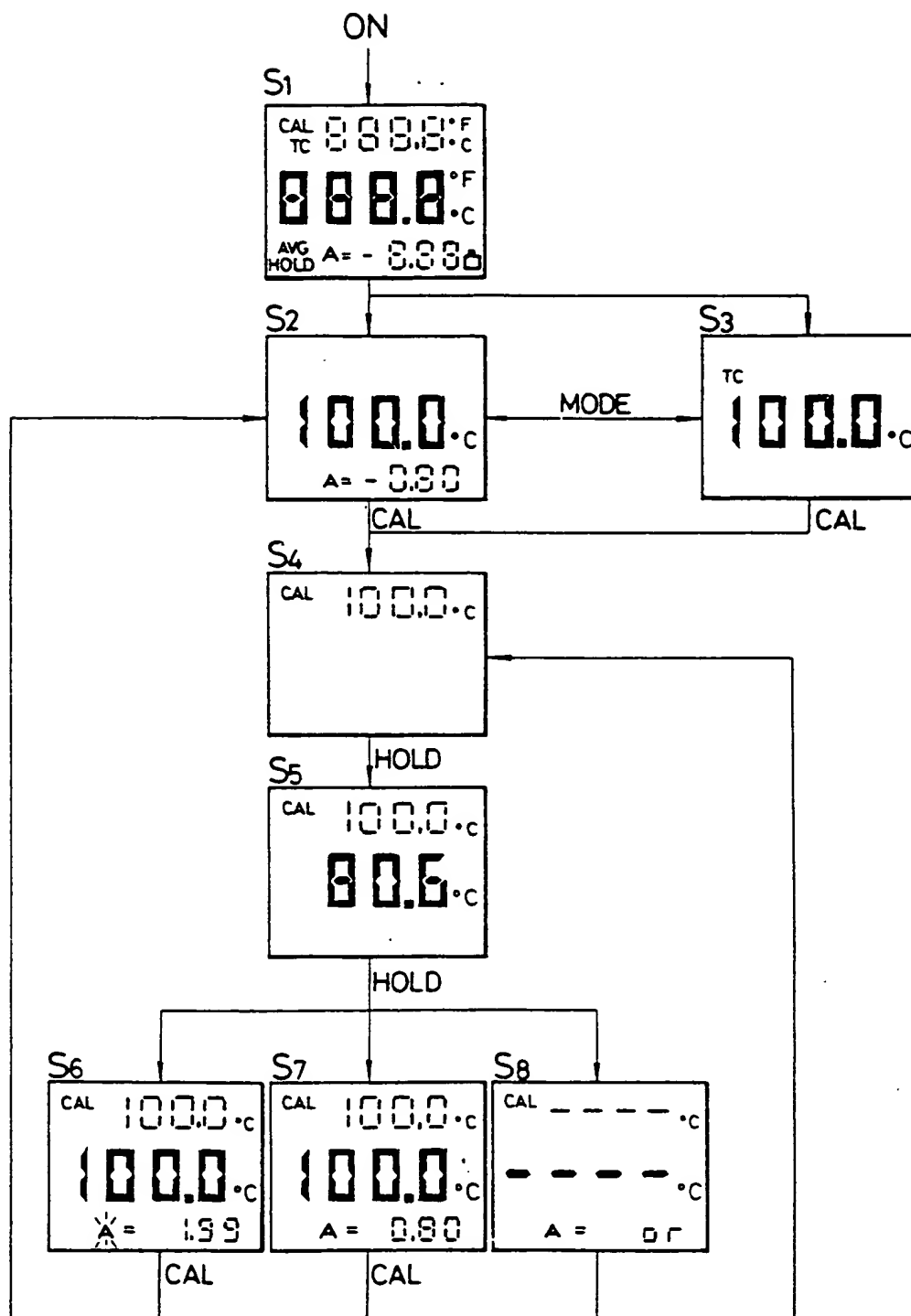FIG. 4

FIG. 5

FIG. 6

(a)

(b)

(c)

(d)

FIG. 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 95 11 3225

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-5 186 541 (PAULK RAYMOND C) 16 February 1993 * column 4, line 24 - column 5, line 31; figures 1,3 *	1,7	G01J5/00
X	EP-A-0 442 351 (ULTRAKUST ELECTRONIC GMBH) 21 August 1991 * column 4, line 45 - column 7, line 8 * * column 8, line 25 - line 28 * * column 8, line 41 - line 57 * * figures *	1,7	
X	US-A-3 777 568 (RISGIN O ET AL) 11 December 1973 * column 2, line 42 - column 4, line 3 * * figure 1 *	1,7	
A	US-A-4 634 294 (CHRISTOL JAMES T ET AL) 6 January 1987 * column 2, line 38 - column 3, line 58 * * figure 1 *	1,7	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 September 1996	Krametz, E

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